Making short haul air trips in India seamless and attractive:
Integration of alternative transport technologies to improve airport connectivity

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ABSTRACT

Air transportation is attractive because of time saving and its role has been increasingly becoming necessitated by deregulation, privatisation and globalisation. It is common in short haul routes that the ratio of airtime to total journey time to accomplish the travel is very small and adverse to have attraction. The access and egress to and from airport facilities is extremely important. The need to improve connectivity in terms of capacity and rapidity to existing and new airports with alternative urban transport technologies like Metro Rail, Light Rail, and Monorail has been emphasised in this paper considering the rapid expansion of civil aviation, starting of operations by new airlines in India and air travel is becoming a need as against luxury in the past. The sharp increase in air travel in India over the last two years indicates that the future growth in air traffic will be fuelled by feeder air sector, as the hinterland opens up industry, service and tourism. To derive fully the advantages of short haul air transportation, the integration of transport systems with necessary logistics feeding each transport modes is necessary to perform a seamless journey. This paper aims at addressing these issues also and generates an argument for the need of planning urban transport technologies in a complimentary role for the growth of short haul air routes in India. It is very important to consider at the conceptual stage, the integration of urban transport/traffic management schemes. Such established schemes will make short haul air trips in India seamless and attractive which in turn will help for further growth of civil aviation, thereby enabling India's economic development. Further, issues such as perspectives in city planning and traffic management systems, maintenance-repair-overhaul services of air fleet, Air traffic management infrastructure and human resource development, which also play a catalytic role and prudent to the success of short haul air transport are highlighted in this paper.

Keywords: Short haul air travel; airport connectivity; rail based urban transit systems; multi-modal infrastructure; implementation policies

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1. INTRODUCTION

Air transportation is attractive because of time saving and its role has been increasingly becoming necessitated by deregulation, privatisation and globalisation. Here, an attempt is made to look at potential bottlenecks associated in short haul air travel in India with emphasis on the present system of airport connectivity. It is common in short haul routes that the ratio of airtime to total journey time to accomplish the travel is very small and adverse to have attraction. The airport connectivity assumes importance because in future many unutilised airstrips will be made operational in addition to modernisation of 35 non-metro airports in India. Hence, there is an urgent need for improving the connectivity needs in terms of capacity and rapidity to existing and new airports with alternate urban transport technologies like Metro, light rail transit (LRT), and Monorail. The sharp increase in air travel in India over the last two years indicates that air traffic is surging ahead at 22 to 26 percent growth per annum. Future growth in air traffic will be fuelled by feeder sector, as the hinterland opens up industry, service and tourism. Also, short haul air transportation has great potential as a feeder system in the hierarchy of air network in India. The short haul travel, especially for business is somewhat tricky as time is the important element. The access and egress to and from such transportation facilities is extremely important. Added to this, the short haul air transportation is vulnerable to competition from convenient surface transport modes for intercity travel. To derive fully the advantages of short haul air transportation, the integration of transport system with necessary logistics feeding each transport modes is necessary to perform a seamless journey. In that scenario, there is every possibility of making short air haul travel attractive coupled with a viable pricing policy.

This paper aims at addressing these issues and generates an argument for the need of planning urban transport technologies in a complimentary role for the growth of short haul air routes in India. The transport infrastructure in many Indian cities has not kept pace with trends in growth of urban; inter city, and air traffic except in a few cities like Hyderabad, New Delhi, Chennai (Madras) etc. The green field international airports planned at Bangalore and Hyderabad need high-speed (like HSR/HST: high speed rail/transit elsewhere in the world) ground connectivity from city centres because the short haul air routes will obviously be an integral system to these hubs. It is very important to consider at the conceptual stage, the integration of urban transport/traffic management schemes. It is believed that such established schemes (in a complimentary role) will make short haul air trips in India seamless and attractive which in turn will help for further growth of civil aviation, thereby enabling India's economic development.

This paper also highlights the following issues, which are prudent to the success of short haul/ feeder air services in India. Further, perspectives in city planning and traffic management systems play a catalytic (spin-off) role for smooth flow of traffic on urban corridors. Also, maintenance, repair and overhaul (MRO) services of air fleet are very much relevant to India to maintain continuity of fleet and having timely turn around services. Air traffic management infrastructure like trained air traffic controllers; instrument landing and night landing facilities also play a vital role. The need of human resource development in terms of trained pilots, aircraft maintenance engineers (AMEs), and Aviation University for imparting training and carrying out research and development (R&D) cannot be overlooked. These issues are relevant in the Indian context by considering the thrust given to short haul/ feeder air services in the new civil aviation policy and increasing competition among airlines to open up air connectivity to potential cities having (unutilised) airstrips.

2. HIERARCHY OF AIR TRANSPORT SYSTEM IN INDIA

The airline network in India can be classified into three categories namely trunk routes [connecting four major metropolitan cities viz., Delhi, Mumbai (Bombay), Kolkata (Calcutta) and Chennai], major routes [connection between major metros and metros, between metros and metros, and between metros and other cities], and feeder routes [connectivity between major metro/metro/major city and low tier cities]. The feeder routes are generally in the range of 100 km to 500 km. As per the 2004 estimates from the data available with the Director General of Civil Aviation (DGCA), India, the number of routes and the passengers carried on these routes are shown in **Table 1**.

Table 1. Hierarchy of airline network in India (Year 2004)

Route	Trunk Routes	Major Routes	Feeder Routes	Total
Definition	Connectivity between 4 Major Metros	Connectivity between Major Metros & Metros, between metros&metros, between metros & other cities (> 500 km block distance)	Connectivity between Major Metro/ Metro/ major city and lower tier cities (< 500 km block distance)	-
No. of routes (per direction)	6	78	76	160
Pax.carried (per week per direction)	42,001	2,35,471	29,462	3,06,934
% of total traffic carried	13.7	76.7	9.6	100

2.1 Airport Statistics

The number of airports / aerodromes in India are 449 and out of these only 211 has ICAO/IATA ID (*Bhargava, DGCA*). The number of airports classified as operational for civilian purpose are 199 (44 percent of total). Out of these operational airports, 84 are managed by Airports of Authority of India (AAI), 87 are under state/ private ownership and 28 are civil enclaves in defence airports. But it is surprising to note that only 65 airports (one third of total operational) are being used by scheduled flights. The **Table 2** and **Figure 1** shows the total airports in India and their operational status.

Table 2. Total airports/ airstrips in India

S.No	Ownership	No.of Airports	Operational	Non-operational
1	State Govt.	57	47	10
2	Private	50	40	10
3	Defense	132	85	47
4	AAI	92	84	8
5	Other airstrips	118	NA	NA
	TOTAL	449	256	75

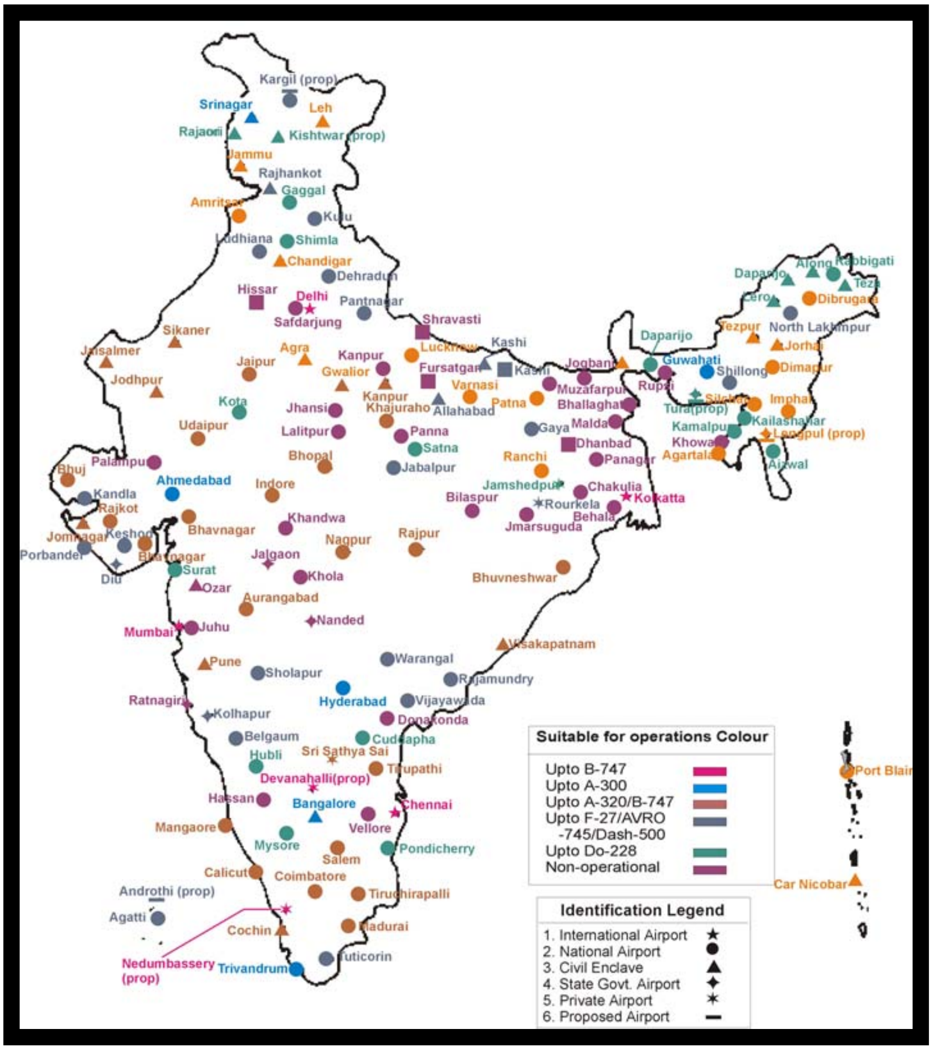


Figure 1. Airports/ Aerodromes in India

2.2 Air Passenger Traffic in India

Based on the preliminary examination of published schedules of three airlines [Indian Airlines (IA), Jet Airways (JA) and Air Sahara (SA)] in India and the DGCA airport statistics, around 65 cities are connected by air. The population of each city, its classification as major city (classified as class A/ tier-I city in India: **Table 3**) and the total passengers handled along with embarked/ disembarked load factors are presented in **Annexure I** (C*ensus, DGCA, Chandra*). Classification of cities merely allows the pattern to be viewed in one more dimension.

Table 3. Classification of cities

Class	Population
A*	> 1 million
B	500,000 to 1 million
C	100,000 to 500,000
D	50,000 to 100,000
E	20,000 to 50,000
F	10,00 to 20,000
G	< 10,000

* includes the 4 major metros

2.3 Impact of low cost carriers (LCC) on upper class rail travel pattern

The time series data on the growth trends in intercity rail (upper class) and air transport shown in **Figure 2** clearly indicates that the introduction of Shatabdi and Rajdhani Rail Services in 1990's might have influenced the price sensitive travellers towards these services thereby increasing the share of upper class rail travel. The reverse trend has been observed during 2003 thus marking the start of LCCs in India coupled with the price war among the three-scheduled airlines viz., IA, JA, AS.

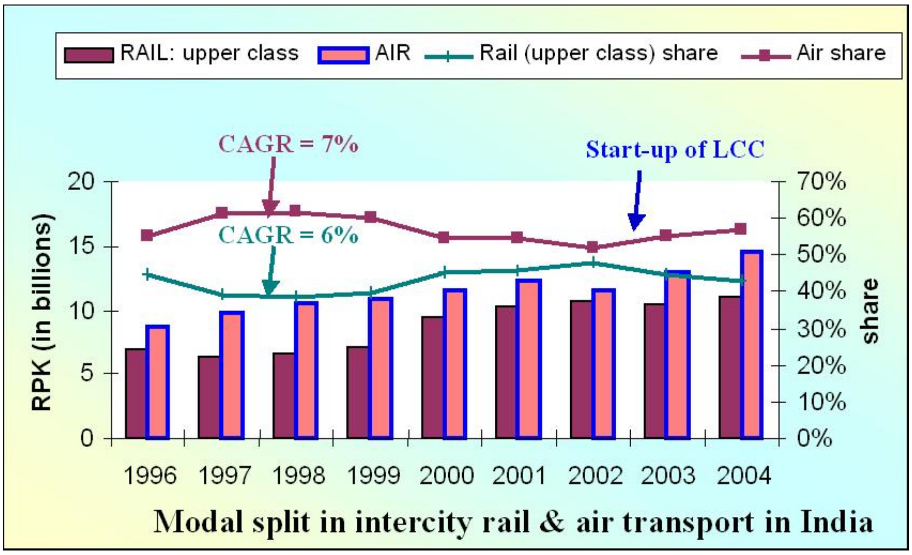


Figure 2. Passenger traffic carried by upper class rail and air transport

2.4 Modernisation of 35 non-metro Airports and Potential Cities

Some 35 non-metro airports in India will be modernised as part of an in-principle approval accorded by the Prime Ministers' Infrastructure Committee in June 2006. The AAI has entrusted the responsibility to draw a plan for a phase-wise development of these airports that includes the development of passenger terminal buildings, land use and city-side infrastructure. In Phase I, it is proposed to develop 10 airports at Thiruvananthapuram, Madurai, Mangalore, Ahmedabad, Amritsar, Guwahati, Goa and Lucknow. The 15 airports that are to be developed during the second phase include Agatti, Coimbatore, Visakhapatnam, Aurangabad, Port Blair and Nagpur. Besides these, studies are underway to identify 10 other airports, which should be taken up for development (*The Hindu Business line*).

Based on the previous studies (*Chandra 2003*, *Kodanda 2003*) and the priority associated with reference to business, tourism, and industry, a list of potential cities are presented in **Table 4**.

Table 4. Potential cities for feeder air connectivity

States	S.No	City
Madya Pradesh, UP, Uttaranchal	1	Jabalpur
	2	Gwaliar
	3	Allahabad
	4	Kanpur
	5	Dehradun
	6	Nainital/Moradabad
J&K, Himachal Pradesh, Punjab	7	Udhampur
	8	Shimla
	9	Patiala
	10	Ludhiana
	11	Jallandar
Maharastra	12	Nasik
	13	Kolhapur
	14	Ahmednagar
Gujarat, Rajasthan	15	Surat
	16	Kesod
	17	Kota
	18	Jaisalmer
	19	Ajmer
	20	Bikaner

States	S.No	City
Kerala, Tamil Nadu	21	Salem
	22	Pondichery/ Tuticorin
Andhra Pradesh, Karnataka	23	Mysore
	24	Hassan
	25	Belgaum
	26	Hubli
	27	Gulbarga
	28	Bellary
	29	Shimoga
	30	Vijayawada
	31	Puttaparthy
	32	Rajahmundry
	33	Kadapa
West Bengal, Orissa, Bihar,Jharkand, Chattisgarh	34	Darjiling
	35	Rourkela
	36	Jaypur/ Koraput
	37	Gaya
	38	Dhanbad
	39	Jemshedpur
North East	40	Shillong
	41	Gangtok
	42	Itanagar
	43	Pasighat

3. URBAN TRANSPORTATION IN INDIA

3.1 Demography

The process of urbanisation is a worldwide phenomenon and India is no exception to this. The urban population in India is growing at a rapid rate. In this process cities are expanding in space and expanded cities generate more demands for passenger transport. The population is on the increase at a pace around 2.5 percent per annum whereas the rate in the increase of motor vehicle population is around 9 to 10 percent per annum. As a result there is a tremendous increase in the transport demands. The number of cities with a million-plus people is expected to go from present 35 to 51 by 2021.

By virtue of the magnitude of population, the urban India is gigantic in size and the urban travel demands in many cities have surpassed the capacities of the only available road based mass transport systems and other private modes of transport. About 280 million people (about 27% of country's population) are reported to be living in urban India in 2001. This is expected to touch a figure of 335 millions by 2011 (*Reddy & Kodanda 2004*). Apart from the gigantism of this population, its skew distribution is critical to all those concerned with the administration and development of infrastructure to serve the needs of urban residents. About 65% of the urbanities in India are situated in class-I cities (population one lakh and above). Not only this, more than 30% of the urban population is located in metropolitan cities (population one million and above).

3.2 Travel Demand in Indian Cities

Socio-economic growth along with the population of Indian cities has resulted in increased travel demand. The per capita trip rates by vehicular modes and the average trip lengths in cities have more or less doubled in the last two decades. For example the per capita trips in Delhi were 0.41 in 1971 and this has increased to 0.91 by 1991 (*Reddy 2004*). Similar increases are reported in many other cities.

A study conducted by Central Road Research Institute (CRRI), New Delhi in seventeen cities on passenger flows in four corridors revealed that peak hour flows in the heaviest corridors (assuming 10% flow as peak hour flow) are more than ten thousand passengers. The observed flows in heaviest corridors of majority of the seventeen cities range from 10500 to 24950 passengers during peak hours. These figures amply indicate the need for proper development of mass transport systems. It is to be noted that the available road widths are too inadequate to carry these passengers, and they mainly travel in individual modes with low occupancies. In the absence of reliable and comfortable mass transport systems, the individual modes are growing exponentially. For example, the growth of two wheelers averages 10 percent per annum while that of four wheelers (cars) averages to 4 percent in metropolitan cities. This phenomenal growth in private modes of transport is going to be detrimental to the sustainability of the cities (*Reddy 2003, 2004*).

The air pollution levels have been constantly increasing and many of the urbanities in India are suffering from respiratory problems. The cities are going to come to a grinding halt with the traffic jams and the residents will face a serious problem of suffocation from the vehicle emissions. Already the parking has spilled on to main carriageways and footpaths in many of our cities. The situation in other state capitals and medium size towns is equally worse when one looks at the environmental pollution. The UN backed inter-governmental Panel on climate change (IPCC) report on global warming indicates that atmospheric concentration of pollutants has touched highest levels (*India Today*).

3. 3 Urban Transport Infrastructure and Systems

It has to be accepted that no serious efforts in planning, designing and construction of appropriate transport infrastructure and systems have been coming forth, in spite of the fact that a number of studies have been conducted and the planners of urban transport are aware of the growing inadequacies and concomitant problems of urban transport in growing Indian cities.

Excepting three or four mega cities like Mumbai, Kolkata, Chennai and Hyderabad where some form of mass rail transit systems exist, the other metropolitan and medium size cities are totally dependent on road transport for intracity travel. In spite of a number of studies, not much progress has been made in providing and developing mass transport systems in any of these cities. While the reasons may be many for this situation, but the result is rapid growth of' individual private as well as hired modes of travel culminating in traffic congestion. In some cities, state owned buses and in some other cities privately operated (licensed) buses cater partially to the travel demands. The situation now is that the expansion in the capacity of bus systems is not feasible for want of

a) Road space in the already built up areas
b) Already congested condition of traffic

It therefore becomes inevitable, for the sustainability of cities; a new form of transport systems will have to be considered.

4. AIRPORT-CITY CONNECTIVITY

Earlier attempts on economic aspects of rail access to airports were made by Gosling (1986). Rallis et al (1990) emphasised the role of traffic connection between airports and city centres. Further, elaborating on this issue they felt that the increasing implementation of high-speed rail access offering a high door-to-door speed, would change the development of many airports, especially those that lack suitable access-egress transport system. Airport planning and city planning should be closely integrated (Rallies et al 1990). Though these issues have been debated widely, the integration is never been the case in many countries (except in few US and European cities) and India is no exception to this. The capacity of traffic connections to airports is an important catalyst for enhancing the potential of short haul air travel. If the arriving traffic reaches the capacity of the roads, the traffic flow will be delayed. In that case the other alternatives would be to increase the capacity of the transport system either by widening of roadways or opening up of new railway connection. As in majority of the cities, it is not possible for further improving the road capacity due to non-availability of space. In that scenario the options available in the Indian context are either mass based bus or rail transit systems viz., Bus, Metro, light rail, Monorail etc. The exact planning and execution of these transport facilities should be taken up on city-by-city basis.

The passenger traffic between city and airport consists of two parts namely airport generated traffic viz., air passengers, visitors to the airports, airport and service related employees. The other part is non-airport related traffic that uses the same traffic connections living in the catchment area between airport and the city centres and the domestic areas proximity to the airport. It is expected that the mobility levels will increase on short haul sectors due to majority of middle class preferring to use air transport in view of increased income levels. The choices which have been motivated for this change is due to consciousness of time savings associated with air travel and to have the experience of air journey. Almost 40% of Air Deccan's (India's first low cost carrier, began operations in August 2003) passengers are first-time fliers (*O' Connell & Williams 2006*). The budget airlines in India are growing exponentially and are forcing other incumbent airlines to cut costs further. India being a world's largest democracy, the airline travel is also getting 'democratised' owing to the fact that the large number of people travel in planes in both low-cost carrier's and on short-haul routes (*Narain 2006*). Now, the mode of air transport is expanding its market, competing with cheaper railways, roadways, and other modes of transport (premium taxis and luxury A/C buses). Experts believe that airline sector in India is fast growing and to sustain this growth, effective airport-city connectivity is essential for the success of short haul air transport.

4.1 Access and Egress Time

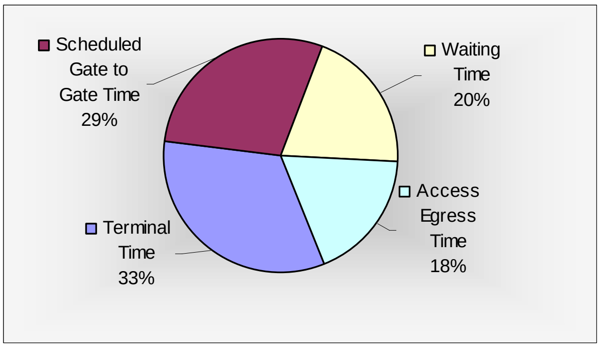
Travel times in access to airports are greater by public transportation than by private vehicles by approximately 2-3 times. But this notion of differentia between public or private may not be valid any more at least in some of the Indian metropolitan cities wherein the traffic congestion levels are unimaginable. The earlier studies reveal that a 10 km distance takes 30-35 minutes by private vehicles and around 65-65 minutes by public transportation (Rallies et al). The Indian experience shows that for a typical radial corridor in Bangalore city [starting from central business district (CBD) to HAL Banaglore Airport], a 15 km distance took around 30-40 minutes by private vehicles and around 60-70 minutes by public bus transport in 1998-99 (*CRRI 1999*). The current traffic situation is entirely different in the sense that the corridor is choked with traffic jams and there is no distinction between peak and off-peak hours during weekdays. The prevailing journey times have increased two fold in the last 5 years. The experience shows that often the passengers spend more time travelling on the access and egress parts of an intercity journey than on the actual air journey (**Table 5**).

Table 5. Proportion of access and egress time as compared to total journey time

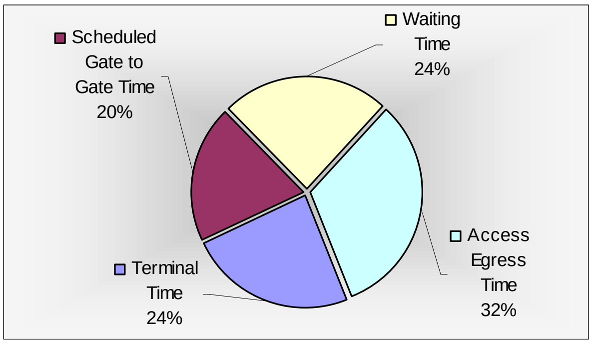
S.No	Details	Air Distance (km)		Rail Distance (km)		
		300	1000	300	400	1000
1	Travel speed (kmph)	250	700	200	200	200
2	Travel time (hours)	1.20	1.43	1.50	2.00	5.00
3	Average travel speed, kmph (door to door)	100	300	133	133	133
4	Average travel time, hours (door to door): Actual travel time+delays + access & egress time	3.00	3.33	2.25	3.00	7.52
5	Delays+access & egress time (hours)	1.80	1.90	0.75	1.00	2.52
6	Delays	0.00	0.80	-	-	-
7	Access & egress time (hours)	1.80	1.10	-	-	-
8	Percentage of access & egress time to total journey time	60	33	-	-	-
9	Ratio of actual travel time to total journey time	0.40	0.43	0.66	0.66	0.66

Source: compiled from Rallis et al

It is clear from **Table 5** that for distances of 300 km by air, the air travel speed is 250 kmph and average journey speed (door-to-door) is 100 kmph and constituting approximately 60% of the total travel time as access and egress time. The international experience indicates that for 300-400 km distances there is only little difference in door-to-door speed for fast rail and air transport. Similarly for distances of 1000 km by air the air travel speed is 700 kmph and door-to-door speed is 300 kmph and approximately 33% is access and egress time (Rallies et al). A study conducted by Volpe in cooperation with NASA shows that 29% of total door-to-door trip time is the actual gate to-gate time for the airliner for trips under 500 miles [**Figure 3(a)**]. Similar observations in India shows that gate to-gate time and access-egress time accounts approximately 20% and 32% of total trip time respectively for a typical 800 km distance [**Figure 3(b)**].



3(a). for Volpe commercial airline (*Source: Moore 2003*)



3(b). for a typical Indian city pair

Figure 3. Typical breakdown of door-to-door trip time

The airport travellers often cannot afford to depend on the average access time and risk involved in missing a flight. The bottlenecks associated with traffic congestion result in increased access time in the access routes to most of the Indian airports. Improved access time on corridors leading to airports is not only beneficial to air passengers, visitors to the airport, airport and service staff but also to domestic traffic proximity to access corridors and traffic to Tech parks located close to airports

The promoters of modernisation as well as builders of airports viz., GMR group (New Delhi), GVK group (Mumbai), Bangalore International Airport Limited (BIAL), Hyderabad International Airport Limited (HIAL), and AAI should indicate their sourcing plans for access and egress transport services with respect to the airports being built / upgraded / modernised. This will greatly help the transport planners to draw the traffic management schemes very effectively. The transport planners in turn need to generate strategies to gain a better understanding of various ground based transport systems available for fast movement of traffic between airport and CBD.

4.2 The Case of Existing Bangalore Airport to City Connectivity

4.2.1 From Garden/ Silicon City and now to India's first green field airport city

Bangalore is situated at an altitude of 920 metres above sea level, and is the principal administrative, cultural, commercial and industrial centre of Karnataka. The city, which is spread over an area of 2190 sq. km, enjoys a pleasant climate throughout the year. Bangalore's tree-lined streets and abundant greenery have led to it being called the Garden City of India. However, since local entrepreneurs and the technology giant Texas Instruments discovered its potential as a high-tech city in the early 1980s, Bangalore has seen a major technology boom. It is now home to more than 250 high-tech companies, including homegrown giants like Wipro, Infosys and Biocon etc. Consequently, Bangalore is now called the Silicon City of India. Once the Devanahalli International airport (see **Annexure - II**) comes into operation in Bangalore, it will be a '*first green field airport'* in India.

4.2.2 Traffic Scenario and Main Bottlenecks

It takes 60-80 minutes to fly between Bangalore and Mumbai covering around 800 km of air distance. But driving along the 5.3 km stretch from Trinity circle (one end of Mahatma Gandhi Road) to the airport takes more time, thanks to the bottlenecks and gridlocks. The airport has 11 intersections (see **Figure 4**) and a flyover, of which four intersections have signals, four are manned and two are unmanned. With a large number of Information Technology/ Entrepreneur Service (IT/ITES) companies coming up in the International Tech Park Bangalore (ITPB) and proximity to the existing airport, coupled with the upcoming commercial/ business activity in Marathahalli, traffic has increased on this road very significantly in the last five years. The number of vehicles heading towards ITPB alone comprises more than those leading to the airport. This is another reason for the congestion on this road (see **Figure 5**). This is a four-lane road having capacity of 4400 PCUs per hour. But, presently it caters over 10,000 PCUs (more than two times its capacity) during peak hours.

The flyover at Indiranagar 100 feet road –Koramangala intermediate ring road (IRR) junction is expected to be fully operational shortly. This was a bottleneck until the loop connecting Koramangala to Indiranagar came as a relief. Another major obstacle on this road is movement of buses on this high-density radial corridor/ route. The existing narrow bridge at Marathahalli (**Figure 6**), which connects to ITPB, Whitefield, Varthur etc is another major bottleneck now. Bangalore Metropolitan Transport Corporation (BMTC) buses heading to ITPB, Marathahalli, Whitefield and buses belonging to Hindustan Aeronautics Limited (HAL), National Aerospace Laboratories (NAL), and Indian Space Research Organisation (ISRO) occupy major portion of the airport road particularly during morning and evening rush hours. During the construction of a culvert on NAL Wind Tunnel Road, the portion of traffic towards Yamalur, Software Companies (near Chellagatta) has diverted to Airport Road, which had caused further hardships. The completion of this culvert has partially eased the traffic on a section of airport road. Added to these, commercial establishments have come along the way (ribbon development) leading to haphazard parking and other entry-exit problems.

For example motorists take more than 90 minutes to cover a distance of 8 km, whereas a VVIP convoy needs just 15 minutes to cover the same distance (between Airport and Raj Bhavan). This clearly explains the plight of air passengers taking a flight. Such a situation leads to think of a solution as to how they can reach the airports in time.

Intersections:
1. ACS centre (signal), 2. Cambridge road junction (signal),
3. Domlur Aralimara Junction (manned), 4. Domlur Tank Junction (manned),
5. Indiranagar 100 ft Junction (flyover), 6. Manipal Hospital juntion (signal),
7. ISRO junction (signal), 8. Visveswaraya college junction (unmanned),
9. Rajeswari junction ((unmanned), 10. Airport arrival juntion (manned),
11. Airport departure junction (manned)

Figure 4. Layout of Airport Road from Trinity circle to Airport Terminal

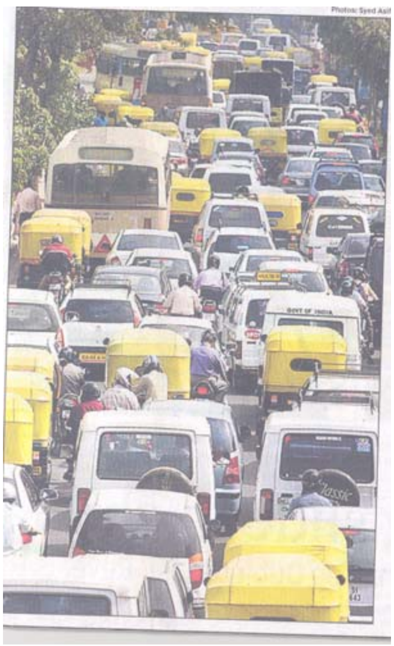


Figure 5. Traffic congestion on Airport Road

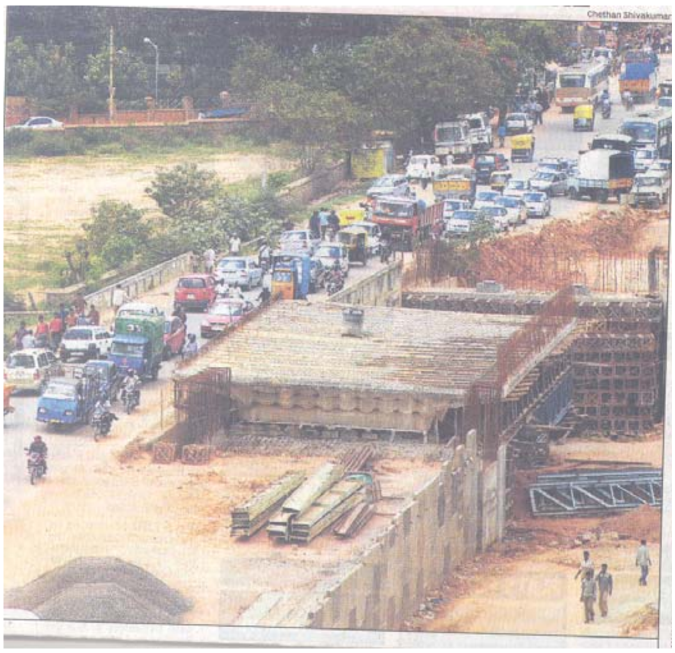


Figure 6. Construction of 3-lane ROB near existing narrow bridge at Marathahalli

(Source: The Times of India)

4.2.3 Remedial Measures

Short-Term:

- Discourage IT/ITES sector employees from personal transport especially with single occupancy.
- Run point-to-point public transport system from and to airport like connecting major points in the city as was done a year ago.
- Expedite construction of new 3-lane railway overbridge (ROB) at Marathahalli. (**Figure 5**) Once this is completed, the traffic delays to Airport bound vehicles from ITPB; whitefield etc (East Bangalore) can be avoided.
- Avoid heavy vehicles plying during day tine on this road.

Long-Term:

- Have helipads in CBD and other areas to ferry VVIP and corporate/ business personnel in helicopters.
- Expedite road-widening work on Suranjandas Road, which connects Old Madras Road to Airport Road. Once this is done, vehicles from north Bangalore to the airport can take this road and avoid the trinity circle route.
- Extension of the proposed Metro alignment from Trinity Circle to ITPB (via Airport Road, Marathahalli) (see **Annexure –IIIa**), or extension of proposed monorail alignment to ITPB via airport road, Marathaahlli (see **Annexure–III b**).
- To develop residential complexes close to ITPB for its employees thus avoiding daily trips from work place to home.

5. RAIL BASED TRANSIT SYSTEMS

A variety of rail based transport systems have been employed worldwide to cater the intracity (urban) travel. The popularly known rail based systems can be classified as

I) Mass Rapid Transit System (MRTS)/ Metro Rail

II) Light Rail Transit System (LRTS)

III) Electric Tram (Trams)

IV) Mono Rail Transit System (Mono Rail)

The capacity and adaptability of these systems vary widely with the travel demand. The capacity of various rail based transport modes in comparison to the road based transport modes are presented in **Table 6**.

Table 6. Capacities of various transport modes
(source:Kodanda & Reddy 2004)

Type	S.No	Mode	Capacity , (Passengers/hour/direction)
Road based systems	1	Car/scooter	10,000
	2	Mini bus	15,000
	3	Standard bus	30,000
	4	double decker bus	35,000
Rail Based System	1	Heavy Rail	20,000 - 105,000
	2	Metro	20,000 - 80,000
	3	LRT	20,000 - 62,500
	4	E.M.U	20,000 - 56,000
	5	Monorail	10,000 - 20,000

5.1 Mass Rapid Transit System (MRTS)/ Metro Rail

Generally, where the travel demands are very high and range between 20000 to 80000 passengers per hour per direction MRTS is employed (**Figure 7**). MRTS is more suitable where the travel demand is less fluctuating and more or less uniform through out the day. MRTS would necessarily be operating on exclusive right of way provided with heavy rails either on surface or elevated or underground. A unit of MRTS may consist of 6 to 10 cars having passenger carrying capacity of 150 (with standees in high density) per car. This usually operates at very high speed (100 kmph) and supported by feeder services like LRT, bus transit or trams. The system operation requires sophisticated signalling system and high technology of construction and maintenance of tracks. The cost of construction and operation is probably high.

5.2 Light Rail Transit System (LRTS)

Light rail transit system operates on dual rails with single or more cars. This system is flexible in terms of the right-of-way. The system by virtue of its technology can operate with other road vehicles by sharing the carriageway or on an exclusive carriageway and permit loading from low or raised platforms (**Figure 8**). In terms of capacity, LRTS will have more capacity than the bus transit and lower than the MRTS. LRTS is favoured to bus transit because it offers comparatively higher speed and capacity with lower costs than MRTS besides the environmental friendliness. By appropriately choosing the number of tracks and transit units **(**one or more cars) capacity can be flexibly adjusted to suit the requirement. LRTS is also susceptible for upgradation to MRTS stage, if planned suitably at the initial stage (*TRB, OECD, Reddy 2004*).

5.3 Trams

These are electric powered vehicles operating on dual rails embedded in the carriageway of the roads or streets. Since they are sharing the same right of way as the road vehicles the problems of congestion and their effects on trams are unavoidable. The trams don't require exclusive carriageway (**Figure 9**) hence cost effective as compared to LRTS. The speed of operation is also lower as compared to LRTS. Passenger carrying capacity may be comparable with the lower end class of LRT.

5.4 Mono Rail System

Normally monorail system is elevated above the ground level and has usually a single car with seating capacity varying from 10 to 30 and the standees are discouraged in this system. Thus the capacity offered by mono rail is very low and may be even less than that of a bus transit many times. A typical monorail transit system is shown in **Figure 10**.

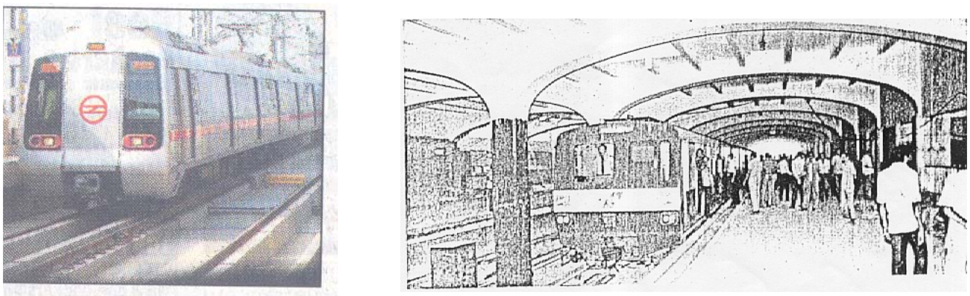
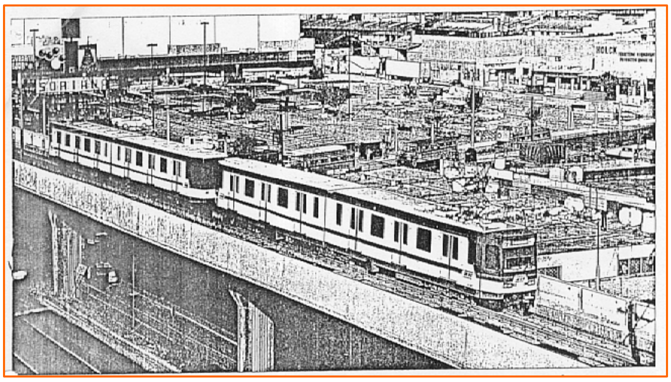
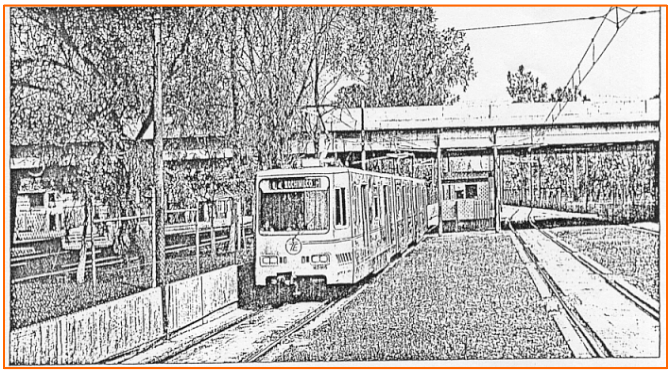


Figure 7. Mass Rapid Transit System/ Metro Rail



8(a). Elevated



8(b). At Grade

8(c). Underground

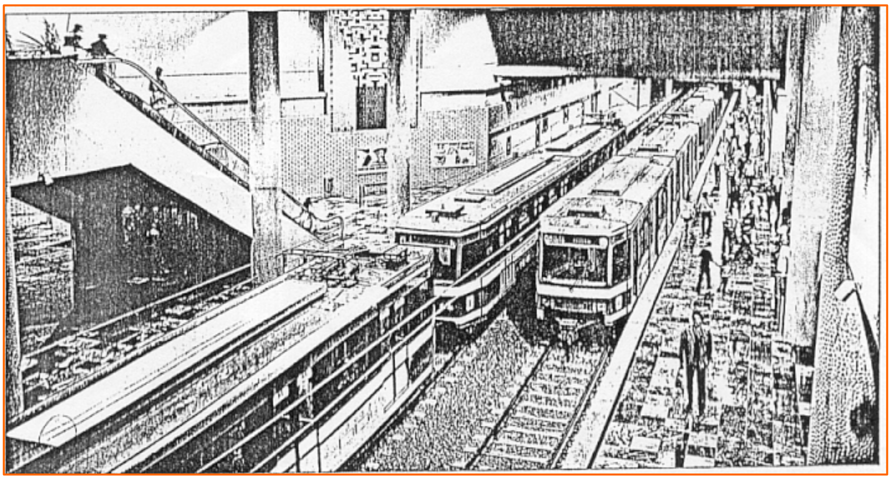


Figure 8. LRTS under different operating conditions

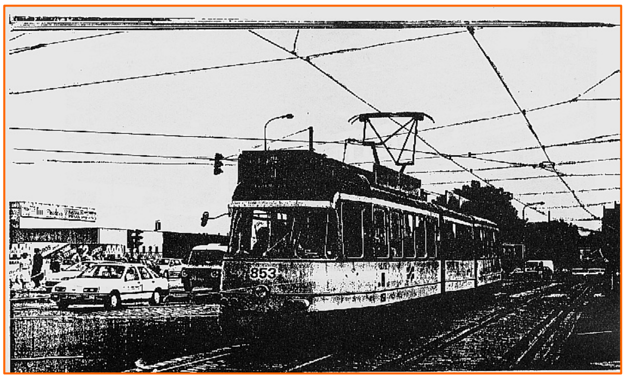
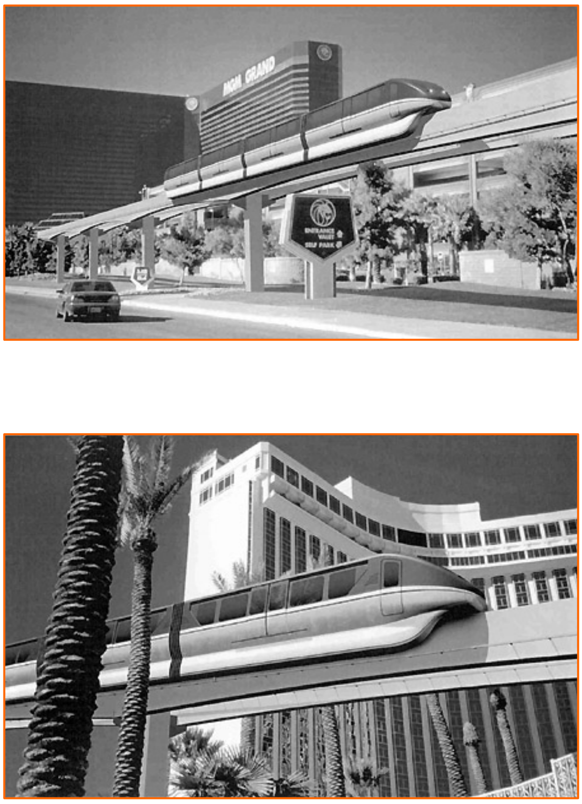


Figure 9. Tram operating with other road vehicles



10(a). Los Vegas monorail 10(b). Sydney monorail

Figure 10. Monorail Transit System

(*Source for Figures 8 to 10: TRB, OECD, LRT websites, Kodanda & Reddy 1998)*)

5.5 Rail based urban transport projects in India

The projects successfully implemented in India are Kolkata (Calcutta) Metro, Delhi Metro, Chennai (Madras) Mass Rapid Transit System. The Bangalore Metro Rail project is now inching towards in finalising bids and tenders. The actual work took off on 15th April 2007. The Prime minister of India Dr. Manmohan Singh laid the foundation stone for this major infrastructure project (Rs. 6400 crore) in July 2006. The Bangalore Metro Rail Corporation (BMRC) was established to implement the project.

5.6 Integration of Transport Modes

The airport ground transportation system is receiving increasing attention from airport authorities and regional planning agencies. The need to plan for airport connectivity and the impact of traffic surrounding the airports, emissions generated by this traffic are forcing airports to consider strategies to mitigate traffic congestion and proper management of ground access traffic. In view of this, there is need for transportation agencies to address the integration of transportation modes, including coordination between the air and surface components of the transportation system. Improving access-egress for airport, from the standpoint of travel time, cost, or convenience involves difficult trade-offs (*Gosling 1997*).

International experience demonstrates that the real competition may come from the new high-speed rail. The Sweden case study shows that the HST operating the Stockholm to Gothenburg corridor has carried around 150,000 passengers during 1991-93. Some 60 percent of these passengers have shifted from air to rail due to marginal difference in the total journey time (15 minutes difference) and a cost saving of about 50 pounds. Atlantic Southeast Airlines (ASA) airlines have responded by reducing airfares to compete on internal routes with rail and the car (*Banister 1993*).

5.6.1 Feasibility studies of rail access projects

The feasibility studies of rail access projects are likely to be improved if the airport links are part of a regular corridor service. Not only does the non-airport traffic using the corridor service help offset the cost of operations, but heavy traffic flows will support more frequent services, thus increasing the attractiveness of rail services to air passengers (*Gosling 1986*).

Gosling rightly points out that the reduction in roadway traffic from rail access projects greatly benefits a wider society than just air passengers and airport employees. Further he summarises that the identification, evaluation and implementation of airport rail access projects goes well beyond technical issues, and need to address regional development and land-use patterns and the role of the regional airports within the overall transportation system. Such integrated transportation systems greatly contribute to air quality and land use development.

5.6.2 The past as prelude to future

Constructing rail facilities on a 'green field' site is much easier, but the need to closely integrate the stations with airport terminal buildings requires a major capital outlay. Gosling (1997) mentioned that an alternative approach for improving inter-modal links with the help of off-airport terminals was in practice else where in the world in 1960s and 1970s. The first off-airport terminals were in operation in the CBDs of such cities as London, New York, and San Francisco usually by individual airline or for lease to airlines. Further he states that perhaps the best-known off-airport terminal was the East Side Airline Terminal in Manhattan in the USA (**Figure 11**). But steadily the airlines began to discontinue check-in and the patronage declined steadily until the owners of the buildings decided to use them for other commercial purposes. Similar stories can be told about such city centre terminals in India too. For example in Bangalore, the state owned Indian Airlines has in 1960s and 1970s had a pickup point for its travellers from the Mahatma Gandhi Road (CBD) to the airport. In the San Francisco Bay Area, Marine Airporter has served San Francisco International Airport from an off-airport terminal at Larkspur Landing in Marin County (**Figure 12**) since 1985. American Airlines operated a ticket office at the terminal, and for several years American Airlines and United Airlines provided check-in facility from this terminal.

Figure 11. East Side Airlines Terminal (Manhattan, USA)

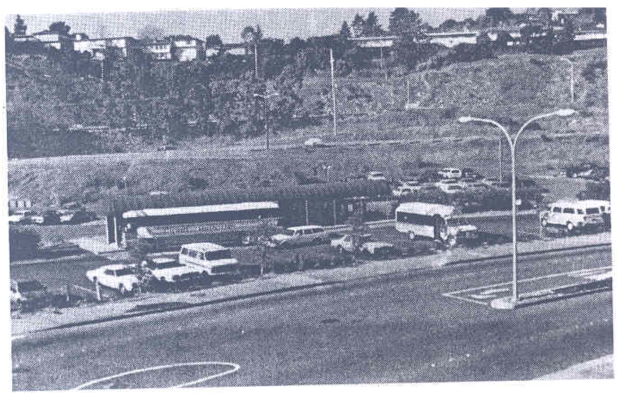


Figure 12. Marin Airporter Larkspur Landing Terminal (San Francisco)

(Source: Gosling Geoffrey. D, 1997)

5.6.3 Examples from India

The recent move by the Delhi International Airport Limited (DIAL) to coordinate with Delhi Metro Rail Corporation (DMRC) and partially fund towards the extension of the metro rail project from the city centre to the airport. DIAL agreed to provide 10 percent of total cost of the project. The project is estimated cost about Rs. 3,500-3,800 crore. The DIAL committed to provide about Rs. 350 crore for the project, which will run on the New Delhi-Moti Bagh –Airport route (*Business line*). Airport rail access links need to be integrated into the regional rail networks.

The Bangalore Railway Division has put up a proposal before the Indian Railway Board to make Byapanahalli a third railway termainal for Bangalore, in addition to existing Bangalore city and Yeshwanthpur. A fund of Rs. 12 crore has been sought to build three platforms immediately. With the Bangalore metro rail project coming up, the Karnataka state government is in talks with the Railways to make Byapanahalli a multi-modal station. Rail India Techno Economic Services (RITES) has been asked to undertake a study of the proposal, since the state government also wants to connect Byapanahalli to the upcoming green field International Airport at Devanahalli with a high speed dedicated corridor through a Metro rail link. BMRC is carrying out technical feasibility for construction of viaducts (elevated section) and State Government has given the nod to carry out works on proposed alignments.

The planning of Metro Rail System for Kochi city is on anvil. It has been argued that under competitive market regimes bus, rail and airline networks will be gradually structured in a hub and spoke configuration with access to terminals becoming the key elements in maintaining the competition. The effective integration of competing modes is possible, if terminal access is a part of an agreement.

6. THE FUTURE

The sharp increase in air travel over the last few months indicate that air travel is surging ahead at 22 to 26 percent growth per annum. The factors attributed to this are:

- Significant shift of middle class travellers from railways to LCC.
- Airfares are slightly higher than A/C II-tier rail fares.
- India posted a high GDP annual growth rate close to 8 percent.
- Outsourcing of business processes to India and export of software and services resulted in the young middle class suddenly having considerable spare income.

During the first three years (2002-05) of tenth five year plan, the air transport sector has grown at an average annual growth rate (AAGR) of 7%, against the plan estimate of 5%. In 2004-05, air transport witnessed a growth of 24% convincing many in the Govt. that the AAGR of 16% is achievable by 2010. Now the experts forecast that the high rate of increase in air travel is likely to continue. Keeping these growth trends in mind, the government of India is committed to give priority to the infrastructure development in civil aviation sector in the 11th five years plan period (2007-2012). The ministry of civil Aviation (MOCA), Government of India is chalking out plans to set up an advanced 'Aviation University' with the collaboration of Andhra Pradesh State Government at the Begumpet airport (*its operations will be closed once the new green field international airportat Shamshabad is ready*) in Hyderabad city. The University would offer training and research in financing of aviation infrastructure, its economics and other aviation related curricula most likely with the help of already existing Indian Air Force (IAF) centre at Dindugal (in Greater Hyderabad).

Future growth in air traffic will be fuelled by feeder sector, as the hinterland opens up industry, service and tourism. There is a favourable environment for multi-national companies (MNCs) to look forward to India to invest in joint venture (JV) projects apart from the outsource business partner (OBP) regime. The recent move by the tourism organizations to provide `package tourism' will have potential attraction to domestic as well foreign tourists and may improve shuttle air services. Migration from rail to air is likely to be on the increase due to high disposable income, aggressive reduction in airfares in a competitive environment and comfort, convenience, and lesser travel time associated with air transport. Feeder services can augment better air connectivity in terrains because it is cheaper to build an airstrip than to provide surface connectivity. Apart from this, short haul air transport has great potential as a feeder system in the hierarchy of air network in India. The 14 seater SARAS aircraft development programme at NAL [a constituent of Council of Scientific and Industrial Research (CSIR)] is primarily aimed at, to serve feeder routes and herald a new beginning in indigenously manufactured small aircraft operations in Indian Civil Aviation and to tap the potential of air connectivity to tier-III and IV cities. Preliminary discussions are going on to propose a nominal 70 seater regional transport aircraft project also under the 11th five-year plan.

As a prelude this, minor airports can be initially developed for transportation of perishable goods and other freight so that number of trucks plying on the roads/highways can be avoided thereby reducing traffic congestion/ environmental pollution. Policy decisions such as airport infrastructure both at airside and landside coupled with better accessibility to airports either by road system or rail based systems are urgently needed to sustain this growth and further accelerate the growth potential of tier-III and IV cities and put them on the operational air network of India. The international comparison at ten important airport hubs indicates that the non-aeronautical revenue constitutes about 50 to 80 percent on an average of the total Income (*Iyengar et al 2007*). There is a much debate in the Indian aviation domain on two issues. The primary issue is to develop the airports related infrastructure on public private partnership (PPP) basis. And the second issue is concerned with the airport connectivity, which was often neglected in the initial stages when agreements were signed for airport infrastructure development. Further focus and research on airport to city connectivity related infrastructure is very much relevant in the Indian context considering the rapid expansion of civil aviation, starting of operations by new airlines and air travel becoming a need as against luxury in the past. The paper also highlights the following issues, which are prudent to the success of short haul air services in particular and aviation industry in general in India.

6.1 Issues prudent to the success of short haul/ feeder air services

6.1.1 Perspectives in urban planning and traffic management systems

Points to be considered from the perspective of urban/city planning and traffic management systems (TMS) are listed below:

1. Marking of lanes for fast moving vehicles and regulation of truck traffic on main arterial roads, and installation signage boards.
2. Demarcation of no parking areas and regulation of slow moving vehicle movement where ever the traffic congestion is expected
3. Point to point services
   a. *For example introduction of Volvo bus services in Bangalore*
   b. *Running of A/C bus services in Hyderabad*
   c. *Monitoring of taxi system by police*
   d. *Russian experience: Pink taxies operated in Moscow for ladies by ladies*
4. Well defined bus stops and SMS facility to track the bus movement
5. Effective implement of projects like B-TRAC in Bangalore for traffic management/ control systems and also planning more bye-pass roads.
6. Provision for baggage booking at the city (eg., *2010 Common Wealth Games at New Delhi and preparations for off-airport terminal at Cannaught Place*)
7. Provision of Helipads at CBD's and exploration of alternative routes to Airports
8. Multiple effect:
   a. *Complementary aspect of aviation growth and city infrastructure*
   b. *Provision of residential complexes close to corporate/ ITES companies*
   c. *Recruitment of adequate traffic police personnel will helps in controlling of traffic and also promotes in creating more employment opportunities*
   d. *Growth must be in unison*
9. Radial air connectivity from main hubs
   a. *For example the Houston Airport System Network in USA*
   b. Intra-urban mobility mission VTOL air taxi concepts
10. Coordinated and dedicated effort
    a. *Speedy implementation of a proposal to establish a 'National school of planning and architecture' in Bangalore to evolve strategies to integrate transportation, development and environment.*
    b. *Department of Transport for India (like DoT in USA)*
    c. *Political will to implement*

6.1.2 Human resource development

Faced with a mounting shortage of over 500 commercial pilots every year, action has been initiated on several fronts to mitigate the problem. The DGCA is considering to reduce the time period for acquiring a commercial pilot licence (CPL) from 16 to 12 months, and to introduce a multi engine pilot licence (MPL) in 2007. The DGCA may also grant CPL to about 250 foreign pilots in the first quarter of 2007. Currently, about 500 pilots are needed per year whereas only 200 pilots are being trained in India. In all about 2500 pilots are working with 11 airlines in India. Whereas it will require about 3000 more pilots in the next 5 years. DGCA plans to increase the availability of pilots to about 400 per year. There are about 39 pilot training schools in India as of now. DGCA would like to give trainer aircraft to 11 best performing schools. In addition NAL has developed HANSA-3, a light trainer aircraft. This is an important move, as it will help in better and speedy training of the pilots. The intake per session for Indira Gandhi Rashtriya Uran Akademi (IGRUA) will be increased to 100 from 40 at present.

These steps and scarcity of the trained manpower amply indicate that there is a need of human resource development in terms of trained pilots, AMEs, and Aviation Academy/ University for imparting training and carrying out R&D in the country. As a short-term measure, pilots should be trained to operate flights under low visibility conditions due to fog also. This will enable pilots to operate flights under category (CAT)-II of the instrument landing system. In the long run, training to operate aircraft under category (CAT)-III conditions will be required for thick foggy conditions.

6.1.3 Air Traffic Management infrastructure

Air traffic management infrastructure like trained air traffic controllers; instrument landing (to avoid disruptions due to fog) and night landing facilities also play a vital role.

6.1.4 Maintenance, Repair and Overhaul (MRO)

MRO services of air fleet and facilities for bulk storing of aviation turbine fuel (ATF)/ refuelling are very much relevant to India to maintain continuity of fleet and having timely turn around services. It is expected that India will buy more than 500 aircraft (with jet engines) by 2010. However, the infrastructure to support such a growth does not exist. The government of India is planning an investment of Rs. 35,000 crores by 2010 for development of airports and airport services. Also, it is anticipated that to maintain aircraft fleets, the cumulative value of MRO services required during this period will be in the order of Rs. 9,000 crores. Keeping these situations in mind, the aircraft company Airbus is planning to set up training centre, a MRO facility, an engineering and design centre in future at a phased manner in Bangalore. The HAL is planning to set up a MRO facility as joint venture with a multi-national aviation firm at the present domestic airport once the operations are shifted to new International airport at Devanahalli.

6.2 Emerging new urban forms and new transport concepts:

Kasara John's article on the Aerotropolis rightly reminds us of emerging new urban forms around airports. Hence it is relevant to briefly summarise his analysis:

(a) *Airports are shaping business locations and urban development in the 21st century as much as highways did in the 20th century, railways in 19th century, and seaports in the 18th century. Major airports have already become key nodes in economic system.*

(b) *As more and more aviation-intensive business cluster around airports and along transportation corridors are radiating from airports, a new urban form called, as 'Aerotropolis' is emerging; stretching up to 20 km outward from the airports. Clusters of business, logistics, and industrial parks, distribution centres, IT complexes and wholesale merchandise marts are locating along airport corridors.*

(c) *The airports themselves function as the inter-modal convergent centres, analogous to the function of CBDs play in the traditional metropolitan cities.*

Kasara further argues that some airports, such as Amsterdam's Schipol Airport have assumed the roles of metropolitan CBDs by becoming major employment, shopping, and business destinations (see **Figure 13**). Kruckemeyer Kenneth of MIT, USA on a recent visit to Bangalore city has emphasised that ' *A public transport system has to be so good that people must voluntarily use it even if they have a comfortable car'* (*Times of India*

Dec 15, 2006). The Volvo buses introduced in Bangalore and the A/C buses in Hyderabad are a step in that direction.

The future multi-modal airport and intra-urban mobility mission VTOL air taxi concepts are shown in **Figure 14** and **15** respectively. Moore (2003) anticipates that the intra-urban vehicles would further improve point-to-point mobility, providing the ability to travel in the air closer to the destination and decreasing the average separation distance between small airfields. He argues that these mission concept vehicles would be required to support smaller air fields in relatively close proximity to major airports as feeders. Shifting of airports farther away from towns (eg., Pune airport is 30 km away from CBD) will pose transportation problem till such concepts becomes reality. So, concurrent planning of alternative routes as a long-term measure is very much essential.

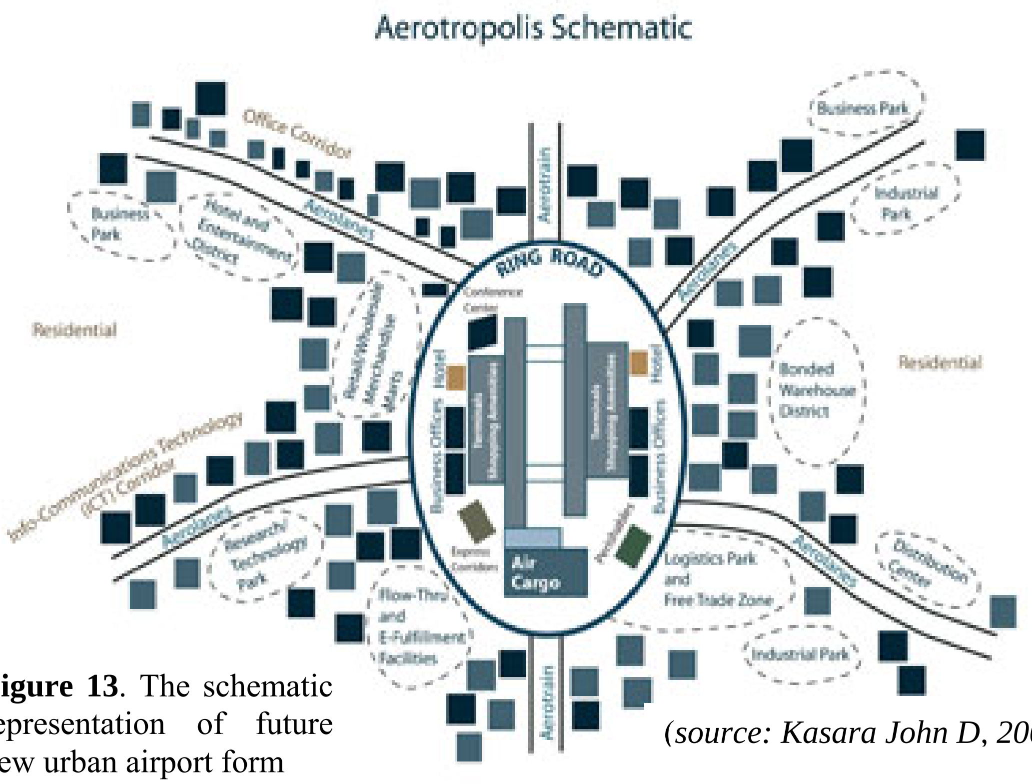


Figure 13. The schematic representation of future new urban airport form

(*source: Kasara John D*, *2006*)

Figure 14. A typical multi-modal Airport (*Source: NASA's SATS project website*)

Figure 15. A typical intra-urban mobility mission VTOL air taxi concept (*source: Moore 2003*)

7. CONCLUSIONS

The number of short haul or feeder routes at present is 71 with another 43 cities as potential candidates for air connectivity. Considering the current increase in passenger traffic and the future growth potential of tier III and tier IV cities, there is a need for creation of feeder air network connectivity in India. The Advent of LCCs has moved traffic from upper class rail to air. Air transport witnessed a growth of 24%-26% in recent times in India as against anticipated growth of 16%. To sustain the traffic growth, the strategies for providing and improving the effective transport system for airport connectivity is to be evolved. In India, Airports Authority of India manages the airports and municipal committees/ development authorities manage city planning. But to address the bottlenecks associated with airport connectivity, general awareness in urban planning and traffic management systems (TMS) is gaining momentum due to prevailing traffic congestion. The earlier perception about whether an airport is a profitable or non-profitable business for a city is being addressed now because of the Tech parks /Special Economic Zones (SEZs) planned proximity to the airports to enhance the economic activity of the cities. The international comparison at ten important airport hubs indicates that the non-aeronautical revenue constitutes about 50 to 80 percent on an average of the total income. The issues related to Public Private Partnership (PPP) in airport infrastructure including airport connectivity under BOT needs to be addressed in the future. The existing common phenomenon of the small ratio of airtime to total journey time to accomplish the short haul travel needs to be looked into by improving the capacity requirements of accessibility to existing as well as proposed new airports with alternative urban transport technologies like Metro, Light Rail, Monorail etc. The access and egress to and from airport facilities is extremely important to derive fully the advantages of short haul air transportation. The development of integrated transport system with necessary logistics feeding each transport modes is necessary to perform a seamless journey. In that scenario there is every possibility of making short-haul air travel attractive with a viable pricing policy.

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References/ Bibliography

Air/ Rail Links – Guide to Best Practice, http://www.atag.org

Banister, D., Anderson, B., Berechman, J., Barrett, S. (1993) 'Access to facilities in a competitive transport market', Transportation Planning and Technology, **17**, pp 341-348.

Bhargava Kapil. (2005) ‘Status of India’s airports. Aerodrome India 2005. Daily show special publication brought out by Indian Aviation, December 7, 2005.

Caves Robert, E., Gosling Geoffrey, D. (1999) Strategic Airport Planning, Pergamon.

Census of India 1991, (2001) (www.censusindia.net)

Chandra, S., Kodanda, B., Sridhar, B.C. (2003) ‘Air traffic stratification in India: Pointers for fleet rationalisation and yield management’, TM CA 0301, NAL, Dec’ 2003.

Chandra, S., Kodanda, B., Yegna Narayan, K. (2003) ‘Micro economic analysis for feeder airline operations in Karnataka’, Special Publication SP 0310, NAL, April 2003.

CRRI. (1999) ‘Traffic and transportation improvement priorities for road corridors of Bangalore’, Final Report submitted to KUIDFC, Karnataka Govt., September 1999.

DGCA, http://www.dgca.nic.in/

Gosling Geoffrey, D. (1986) ‘Economic aspects of rail access to airports’, Journal of Transportation Engineering’, **112** (2).

Gosling Geoffrey, D. (1997) ‘Airport ground access and inter-modal interface’, Transportation Research Record, **1600**, Washington DC.

India Today magazine. April 23, 2007

Iyengar, N.G.R., Ghosh, A.K., Ankur Singhal. (2007) 'Concurrent approach for aviation infrastructure and manpower development'. Paper presented at the 58th Aeronautical Society of India AGM and National Seminar on Aviation Infrastructure in India, Kochi, February 2007.

Janić Milan. (2002) Air Transport System Analysis and Modeling, Transportation Studies Volume 16, Gordon and Breach Science Publishers, Amsterdam, Netherlands.

Kasara John, D. (2006) ‘The Aerotropolis’, www.aerlines.nl, Article dated 14/11/2006.

Kodanda, B., Chandra, S., Yegna Narayan, K., (2003) ‘Market potential for feeder airline operations in India’, Special Publication SP 0309, NAL , April 2003.

Kodanda, B., Pant, R.S. (2004) ‘Emerging issues and current trends in short haul air transport systems’, the 8th World Conference of ATRS, proceedings, Istanbul, July 2004.

Kodanda, B., Reddy, T.S., (1998) ‘The LRT system: The past as prelude to future’, Technical Report, Central Road Research Institute (CRRI), New Delhi, August 1998.

TRB Special Report on 'Light Rail Transit: Planning, Design and Implementation', Transportation Research Board, Special Report **195**, 1982.

LRT websites: www.lrta.org and http://www4.nas.edu/trb/onlinepubs.nsf/web/lrt_news/

Mackett, R.L., Babalik, E. (2003) 'New urban rail systems: a policy-based technique to make them more successful', Journal of Transport Geography, **11**(2), June 2003.

Moore Mark, D. (2003) 'Personal air vehicles: A rural/ regional and intra-urban on-demand transport system', AIAA paper **2003-2646**.

Narain Sunita. (2006) 'CSE news bulletin', (www.cseindia.org), November 16, 2006.

O' Connell John, F., Williams George. (2006) 'Transformation of India's domestic airlines: A case study of Indian Airlines, Jet Airways, Air Sahara and Air Deccan', Journal of Air Transport Management, **12**, pp 358-374.

OECD Report on 'Light Rail Transit Systems', 1994.

Psakari Voula., Abacoumkin Costas. (2002) 'Access mode choice for relocated airports: the new Athens International Airport', Jrnl of Air Transport Management, **8**, pp 89-98.

Rallis Tom and Peen Jens. (1990) 'The traffic connection between airports and city centers', Journal of Advanced Transportation, **24**(3), pp 241-260.

Reddy, T.S., Kodanda, B. (2004) 'Light Rail Transit - A future mode of transport for sustainability in Indian cities', the 10th Triennial World Conference on Transportation Research, proceedings, Istanbul, July 2004.

Reddy, T.S., Madhu, E. (2003) 'A quick method of estimation of traffic flows on urban road network', Technical Note, Central Road Research Institute (CRRI), 2003.

The Hindu Business line (online edition). November 28, 2005 and December 7, 2006.

The Times of India. Bangalore Edition, India, 26/11/2000 and Dec10-12-13-15, 2006.

Yegna Narayan, K., Kodanda, B. (2005) 'Feeder airline operations in India – Present and future', paper presented at Aerodrome India 2005: First International Exhibition and Seminar on Airport Security and Infrastructure, proceedings, Bangalore, December 2005.

Zhang Anming.(1998) 'Industrial reform and air transport development in China', Journal of Air Transport Management, 4(3), pp 155-164.

ANNEXURE - I. Cities connected by air and performance indicators: ELF *

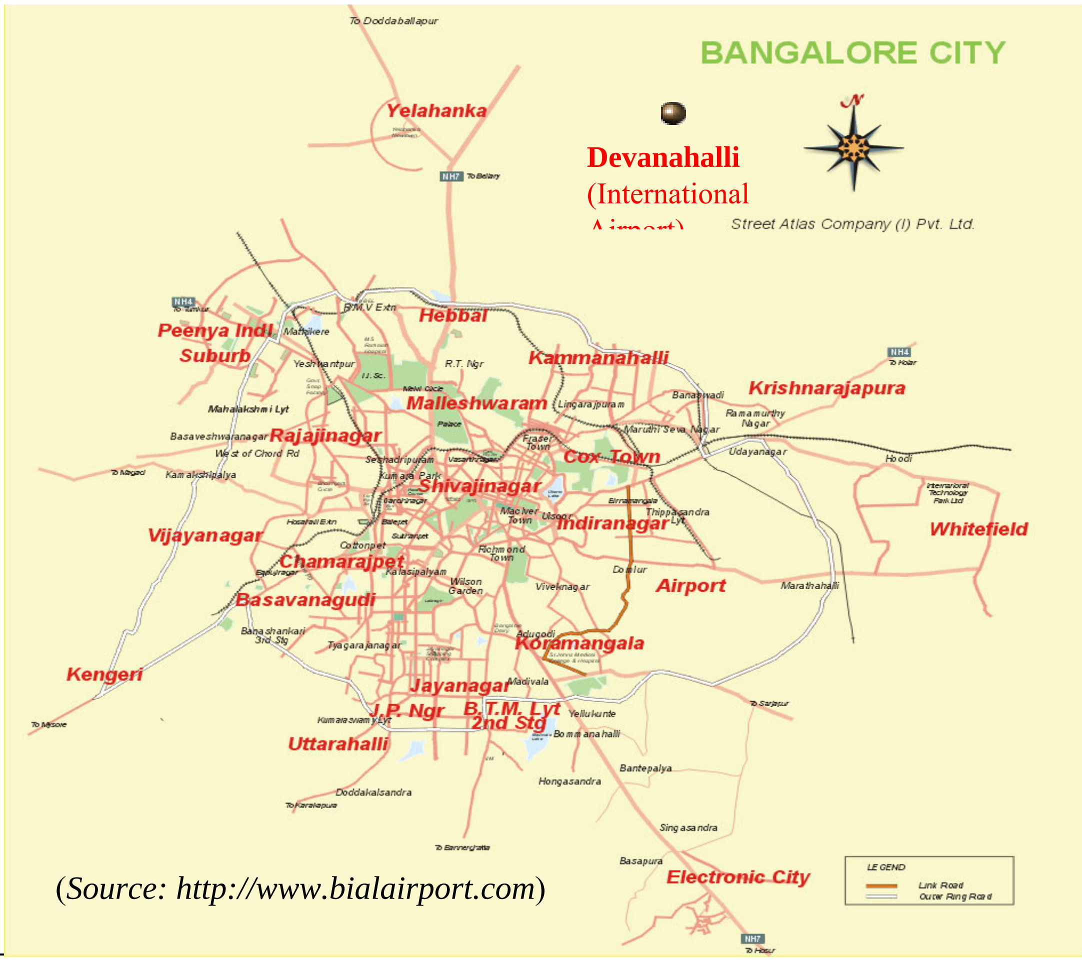
S. No	Airport	Class of city	Region	Population (2001)	Pax. embarked	Pax.dis embarked	No. of outbound flights	AS/week	Weekly LF	
					Per Week (DGCA 2003-04)*			2003-04	emb	demb
1	Mumbai	A:MM	W	16,368,084	76352	76081	956	125214	0.61	0.61
2	Kolkata	A:MM	E	13,216,546	23946	23996	308	38578	0.62	0.62
3	Delhi	A:MM	N	12,791,458	58360	58026	560	96216	0.61	0.60
4	Bangalore	A:Metro	S	5,686,844	25792	26058	340	40012	0.64	0.65
5	Hyderabad	A:Metro	S	5,533,640	15015	16079	214	26200	0.57	0.61
6	Chennai	A:MM	S	5,421,985	24848	23132	245	43160	0.58	0.54
7	Ahmedabad	A:Metro	W	4,519,278	6986	7094	105	14222	0.49	0.50
8	Pune	A:Metro	W	3,755,525	4462	4468	70	10416	0.43	0.43
9	Imphal	A:Metro	NE	2,459,967	1250	1146	18	1946	0.64	0.59
10	Jaipur	A:Metro	N	2,324,319	2440	2309	74	7448	0.33	0.31
11	Lucknow	A:Metro	N	2,266,933	3101	3140	77	8734	0.36	0.36
12	Nagpur	A:Metro	W	2,122,965	2234	2193	42	5036	0.44	0.44
13	Patna	A:Metro	E	1,707,429	1453	1555	42	5642	0.26	0.28
14	Indore	A:Metro	W	1,639,044	2144	2208	42	4386	0.49	0.50
15	Vadodara	A:Metro	W	1,492,398	3042	2970	53	4448	0.68	0.67
16	Bhopal	A:Metro	W	1,454,830	1076	1021	28	3084	0.35	0.33
17	Coimbatore	A:Metro	S	1,446,034	2570	2527	46	6444	0.40	0.39
18	Cochin(Kochi)	A:Metro	S	1,355,406	4571	4473	74	11254	0.41	0.40
19	Vizac	A:Metro	S	1,329,472	1479	1498	25	2646	0.56	0.57
20	Agra	A:Metro	N	1,321,410	183	150	11	378	0.48	0.40
21	Varanasi	A:Metro	N	1,211,749	1542	1691	28	4624	0.33	0.37
22	*Allahabad*	A:Metro	*N*	*1,049,579*	*NA*	*NA*	*NA*	*756*	*NA*	*NA*
23	Amritsar	A:Metro	N	1,011,327	54	66	1	320	0.17	0.21
24	Rajkot	A:Metro	W	1,002,160	1215	1213	25	3528	0.34	0.34
25	Srinagar	B	N	971,357	2448	2433	28	3010	0.81	0.81
26	Aurangabad	B	W	891,841	1095	1027	32	2044	0.54	0.50
27	Trivandrum	B	S	889,191	2396	2373	32	4882	0.49	0.49
28	Calicut	B	S	880,168	1403	1392	39	6602	0.21	0.21
29	Ranchi	B	E	862,850	621	656	21	2002	0.31	0.33
30	Jodhpur	B	N	856,034	846	893		1344	0.63	0.66
31	Trichy	B	S	847,131	112	145	11	800	0.14	0.18
31	Trichy	B	S	847,131	112	145	11	800	0.14	0.18
32	Guwahati	B	NE	814,575	5194	5102	81	10438	0.50	0.49
33	Chandigarh	B	N	783,875	728	730	21	1708	0.43	0.43
34	Raipur	B	E	699,264	719	738	25	2104	0.34	0.35
35	Bhubaneshwar	B	E	657,477	1655	1701	39	5380	0.31	0.32
36	Jammu	B	N	607,642	2067	2092	32	3034	0.68	0.69
37	Jamnagar	B	W	558,462	424	446	18	882	0.48	0.51
38	Mangalore	B	S	538,560	1982	2121	35	3108	0.64	0.68
39	Bhavnagar	B	W	517,578	526	482	11	1102	0.48	0.44
40	*Gaya*	*C*	*E*	*394,185*	*NA*	*NA*	*NA*	*160*	*NA*	*NA*
41	Udaipur	C	N	389,317	1753	1686	46	1740	1.01	0.97
42	Tirupati	C	S	302,678	132	193	7	320	0.41	0.60
43	*Shillong*	*C*	*NE*	*267,881*	*NA*	*NA*	*NA*	*144*	*NA*	*NA*
44	Aijwal	C	NE	229,714	515	488	7	1236	0.42	0.40
45	Bhuj	C	W	209,190	555	610	14	882	0.63	0.69
46	Porbandar	C	W	197,414	129	154	11	396	0.33	0.39
47	Agartala	C	NE	189,327	2016	2010	39	2318	0.87	0.87

ANNEXURE - I. Cities connected by air and performance indicators: ….contd

S. No	Airport	Class of city	Region	Population (2001)	Pax. embarked	Pax.dis embarked	No. of outbound flights	AS/week	Weekly LF	
					Per Week (DGCA 2003-04)*			2003-04	emb	demb
48	Silchar	C	NE	184,285	841	825	21	1512	0.56	0.55
49	Dibrugarh	C	NE	137,879	759	756	42	1512	0.50	0.50
50	Jorhat	C	NE	135,091	257	273	7	504	0.51	0.54
51	Dimapur	C	NE	107,382	278	255	4	588	0.47	0.43
52	Goa	D	W	98,915	6787	6820	84	11870	0.57	0.57
53	Portblair	D	S	93,510	1942	1784	28	2016	0.96	0.89
54	Madurai	D	S	90,073	1127	1236	25	2044	0.55	0.60
55	Tezpur	D	NE	83,028	50	66	2	252	0.20	0.26
56	Diu	D	W	53,135	99	125	7	396	0.25	0.31
57	Leh	E	N	27,513	1272	1282	18	1890	0.67	0.68
58	Khajuraho	F	W	19,282	453	314	7	1638	0.28	0.19
59	Baghdogra	F	E	15,722	1447	1383	25	3218	0.45	0.43
60	Agatti	G	S	7,007	102	100	18	108	0.94	0.93
61	*Lilabari*		*NE*	NA	*33*	*26*	*4*	*144*	*0.23*	*0.18*
62	*Puttaparthy*		*S*	*NA*	*NA*	*NA*	*NA*	*320*	*NA*	*NA*
63	*Belgaum*		*S*	*506,235*	*101*	*82*	*4*	*NA*	*NA*	*NA*
64	Gorakhpur		N	NA	85	93	7	1008	0.08	0.09
65	*Hubli*		*S*	*NA*	*99*	*89*	*4*	*NA*	*NA*	*NA*
					307167			549348		

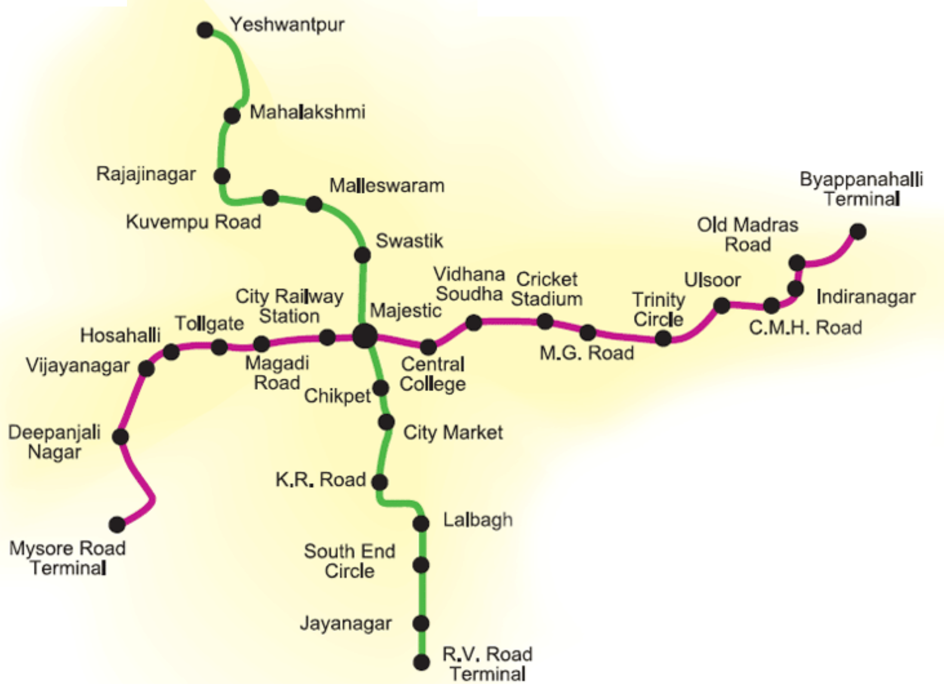
** ELF = embarked load factor, MM = Major Metro, AS = Available Seats, LF = Load Facor, Pax = Passengers, emb = embarked, demb = disembarked*

ANNEXURE-II: Location of India's '*first green field airport*' at Devenahalli



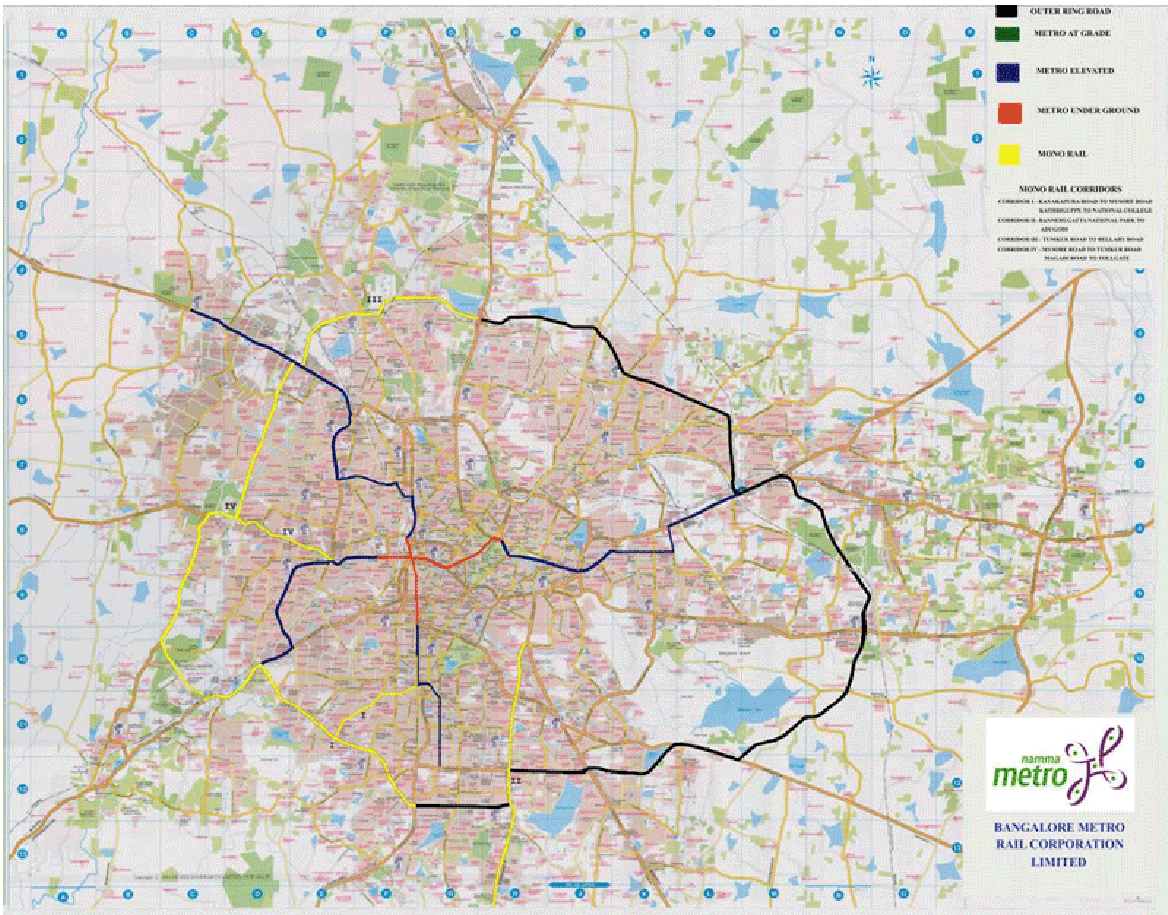
(*Source: http://www.bialairport.com*)

ANNEXURE – III (a): PROPOSED ROUTE MAP OF BANGALORE METRO



(Source: http://www.bmrc.co.in/map.html)

ANNEXURE – III (b): Proposed Route Alignment of Bangalore Monorail



(Source: http://www.bmrc.co.in/mono.html)